Final Examination

US Particle Accelerator School on *Superconducting Accelerator Magnets*
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Question 1:

Your laboratory has just formed a new division called Superconducting Magnet Division. You have joined there as a research scientist to design high field magnets. You are studying the conductor requirements for a magnet that is required to create an integral field of 100 T.m.   In particular, you have been asked to compare these for a 10 Tesla design and for a 12 Tesla design. You have a supervisor who has worked on low field iron dominated magnets powered by copper coils for a long time. He thinks that to first order, the integrated conductor requirements will not change.

(a) Do you agree with him or disagree?   Support your answer with a few sentences without doing any calculation.

(b) Use the following information to compute an approximate value of the required **width** of the insulated cable for a 10 T and a 12 T magnet operating at 4.5 K:

- Critical current density of a 1 mm diameter superconducting wire at 12 T and 4.5 K is 3000 A/mm^2.   In the range of interest the critical current density is inversely proportional to the field on the conductor.

- The peak field on the conductor is 10% more than the central field.

- The current density in copper at the design field (whatever the design field is) should be 2000 A/mm^2.

- The packing fraction of wires in this rectangular cable (before any insulation) is 90%.

- The insulation thickness is uniform on all four sides of the cable and the value of this insulation thickness is 0.05 mm.

Question 2:

What are the allowed harmonics in the following magnet configurations:

(a) A decapole corrector magnet.

(b) A quadrupole corrector connected in series with a dipole corrector.

(c) A normal sextupole magnet having a rotational error of 30 degrees. List the allowed harmonics in the frame of reference of the magnet and in the laboratory frame of reference (Y-axis vertical).

Question 3:

You have made a computer model of a dipole with two intersecting round wires, each having a radius of 5 cm. The two wires carry equal but opposite currents. The centers of the two wires are displaced by 1 cm relative to each other. You put a 10 cm thick iron yoke over the coil with a 12 cm yoke inner radius. You did a constant permeability calculation. However, by mistake you entered $\mu=1$ for the iron properties. In a real magnet, how would the radial, azimuthal, horizontal and vertical components of field drop as a function of radius on: (a) X-axis and (b) Y-axis for a radius greater than 30 cm. (c) Would it be any different if you had specified $\mu=1000$? Answer yes or no without doing any calculation but tell why do you think so?

Question 4:

A flat rectangular coil, as shown in the figure below, is placed in the center of a dipole magnet to measure its transfer function. The normal to the plane of the coil is aligned with the dipole field direction.
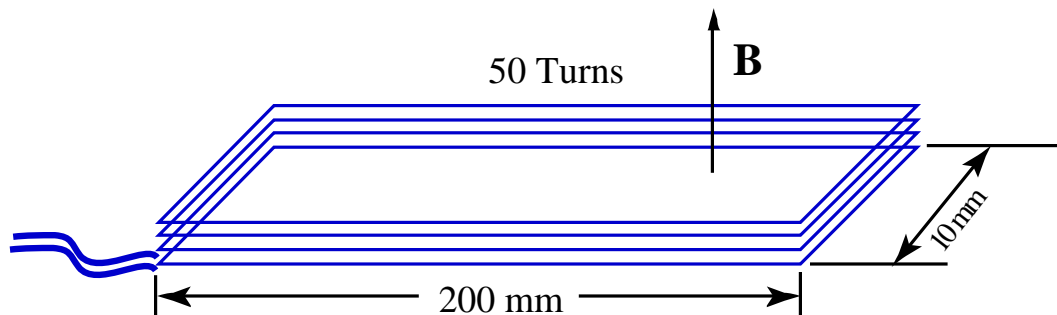
(a) When the magnet is ramped at a constant rate of 100 A/s, the voltage signal measured across the coil is 12 mV. Calculate the transfer function of the magnet, assuming the field in the magnet to be a perfect dipole.

(b) If the field in the magnet has a normal sextupole term of 50 units at a radius of 10 mm, what is the error in the dipole transfer function derived above?